A shear cell designed to probe the velocity-velocity gradient (1-2) plane of shear in complex fluids

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A new shear cell sample geometry for complex fluids is optimized for SANS and USANS structure measurements at the NCNR that probes the most useful projection of the microstructure under flow; the velocity-velocity gradient (1-2) plane of shear (Fig. 1). The new NCNR sample environment is available for use on the three SANS (NG-3, NG-7, and 10m SANS) and USANS (BT-5) instruments at the NCNR and on D22 at the Institut Laue-Langevin (ILL), as a collaborative development with the Center for Neutron Science at the University of Delaware and the ILL, Grenoble, France. Complex fluids encompass, but are not limited to, colloidal dispersions, surfactant solutions, emulsions, gels, glasses, proteins, biomaterials, foams, polymers and block copolymer solutions. Common to all is that oftentimes their processing and use involves flow. Hence, the study of soft matter forced out of equilibrium by shear flow is an important research area to improve formulation, processing, and manufacturing of complex fluids. The unique shear cell sample environment highlighted here represents a significant advance in our ability to understand the relationship between the microstructure of complex fluids and the macroscopic stress exhibited by these materials.

Recent manuscripts [1-3] discuss in varying detail the rheo- and flow-SANS methods. The sealed Couette shear cell sample environment is designed to generate a laminar shear field while simultaneous microstructure measurements are made using SANS or USANS (Fig. 1) [3]. Investigating the evolution of velocity gradient dependent phenomenon, such as shear banding [7], is now possible by performing spatially-resolved experiments using a narrow slit aperture (Fig. 1) [4,5] during start-up flow [6] using time-resolution capabilities available at the NCNR. Example results of a time-resolved flow-SANS experiment (Fig. 2) are shown for a shear thickening colloidal suspension during large amplitude oscillatory shear (LAOS) using time-resolved SANS. The example 2D SANS patterns demonstrate the formation of hydroclusters corresponding to the highest shear rate and can be quantitatively used to determine the mechanism underlying the associated stress response [7,8]. This example illustrates just one of many uses for studying complex fluids under shear flow using the newly commissioned 1-2 shear cell sample environment geometry in conjunction with spatial- and time-resolved neutron scattering methods at NIST. More information about this sample environment, including a video documenting its operation, is available from the Journal of Visual Experiments [3].

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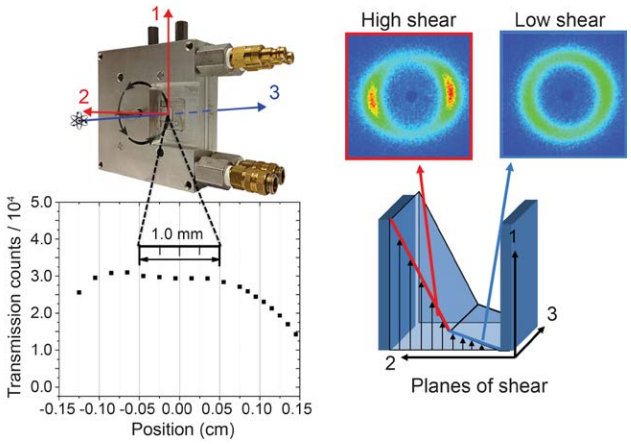

FIGURE 1: Left top: 1-2 shear cell geometry with velocity (1), velocity-gradient (2) and vorticity (3) shear directions indicated; bottom: counts as a function of position across the shear cell gap [3]. Right: Example of spatially resolved shear-banding.

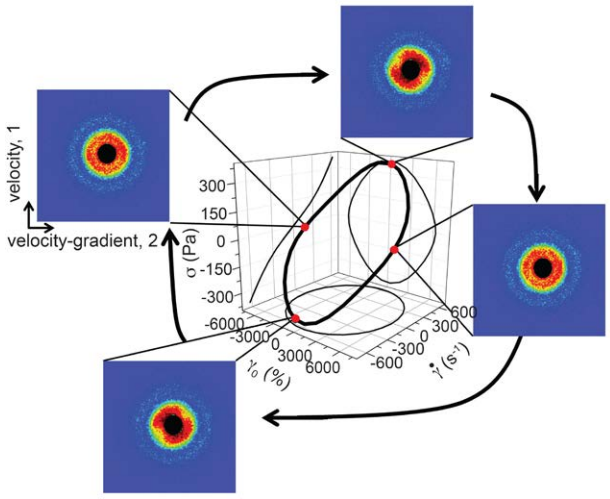

FIGURE 2: Shear thickening fluid (SiO_2 particles in d-ethylene glycol PEG-600 (70/30), $\phi_{effective} = 0.48$) during LAOS (oscillation frequency $\omega = 10$ rad/s and shear amplitude $\gamma_0 = 6278$ %). The black line is the viscoelastic rheometry stress response reported as a Lissajous curve accompanied by 2D SANS results from experiments made in the 1-2 plane of shear.

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